U.S. GRAIN MARKETING RESEARCH LABORATORY

Summary Progress Report—1981

USGMRL, Manhattan, Kansas

Agricultural Reviews and Manuals
Agricultural Resarch Service
U.S. Department of Agriculture

ARM-NC-22
June 1982

PREFACE

This summary report reviews activities and accomplishments of the U.S. Grain Marketing Research Laboratory (USGMRL) in FY 1981. Like the previous reports, it concentrates on what has happened during the past year. It has been a year of continued redirecting of some of our shrinking resources to select those lines of work that should be conducted by the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS), for which USDA-ARS is uniquely structured and equipped, and that have the greatest potential of providing meaningful solutions to important problems. We have found that those objectives can be accomplished best by addressing regional-national-international research problems and by making the best possible use of our two strongest assets: (1) the availability, under one roof, of human and physical resources for interdisciplinary research, and (2) the recognition that long-range basic and applied research, responsive to immediate needs, are companions for successful and valuable research. We have found that the time-proven route from new concepts through applied investigations in the field, laboratory, and pilot plant to development of new products and extension of that information to the user and consumer is still the best return on the taxpayer's investment in research.

The year 1981 has been one of much team work and interdisciplinary and cooperative research. Some of our studies were conducted in cooperation with scientists in other USDA research facilities and in several universities. Most of our collaborative studies were with researchers at the Kansas Agricultural Experiment Station and represented effective and mutually beneficial cooperative efforts. We conducted several collaborative studies within technical committees of the American Association of Cereal Chemists, the International Association of Cereal Chemists, and the Regional Project NC-151 (that has a nationwide and international scope) on marketing and delivery of quality cereals and oilseeds in domestic and foreign markets. An increasing number of projects involved cooperation with action-regulatory agencies in USDA: the Federal Grain Inspection Service (FGIS), Agricultural Marketing Service (AMS), Animal and Plant Health Inspection Service, Foreign Agricultural Service, Agricultural Stabilization and Conservation Services (ASCS), and the Economic Research Service.

The past year has been a difficult one to maintain a center of scientific creativity and sustained research productivity in a changing environment that posed increasing numbers of urgent demands for new information, research findings, and solutions. Excellence in research is expensive and requires flexibility in planning, implementation, and continuity. Those were not easy to come by. Still, it has been a good year. The facts and accomplishments speak for themselves. They are given in the list of publications and oral presentations and are highlighted in this preface.

We have shown that the Golgi apparatus plays an important role in the concentration and transport of storage proteins in maturing wheat. A comprehensive light and transmission electron microscopy study demonstrated the role for the Golgi apparatus in the initiation of protein bodies. Changes in structure and susceptibility to enzymes of enlarging protein bodies were related to functional properties of wheat proteins in breadmaking. The mechanism of modifying starch, proteins, and cell-wall components in the starchy endosperm of malted barley was studied by a combination of histochemistry, light microscopy, and transmission and scanning electron microscopy. Freeze-fracture electron microscopy was shown to be a powerful method in explaining changes in breadmaking, as effected by dough components, mixing, fermentation, and baking.

We found that the quantity of polar lipids or galactolipids occurring naturally in wheat is related to breadmaking (functional) properties and may govern or be closely related to other factors that govern functional properties of good and poor varieties of wheat. The highly significant correlations pointed to the potential usefulness of polar lipids, ratio of nonpolar to polar lipids, or lipid galactose for estimating loaf volume potential of hard red winter wheats. We have demonstrated the role of lipids in reducing dustiness of wheat flour; the potential of following, by polyacrylamide gel electrophoresis, parents in wheat-rye crosses; and the usefulness of differentiating among wheat cultivars of varying breadmaking potential by determining differences in protein solubility.

We compared four methods (work to grind, time to grind, particle size of ground wheat, and near infrared reflectance of ground wheat) to measure hardness of wheat cultivars and samples in marketing channels. The use of the methods to differentiate between dark, hard, and vitreous and yellow hard kernels was studied. A study on the relationship of wheat hardness characteristics of wheats and flours that govern end use properties was conducted.

A colorimetric assay was adapted to determine α-amylase activity of barley malts. The colorimetric assay and a commercial instrument for that assay were used in collaborative studies. The instrument provides a reliable and rapid procedure to evaluate sprout damage; the results are highly correlated with falling number and amylograph assays.

We have found on the basis of extensive small-scale and bin-size tests that total fungal invasion and aflatoxin production by *Aspergillus flavus* could be at unacceptable levels before the grain lost 0.5 percent dry matter when conditions were favorable for fungal growth. The extent of fungal invasion, at storage times equivalent to 0.5 percent dry matter loss, depended on amounts and types of kernel damage and on amounts of fungal inoculum, particularly *A. flavus*. Respiration of grain can be a major contributor to dry matter loss.

Library of Congress no. ISSN 0193-3787

We have continued to evaluate functional (milling and baking) properties of potentially new hard winter wheats. We are proud to be part and one of the focal points of a regional breeding program for the major wheat crop that resulted in producing higher yielding cultivars with increased protein contents.

About 300 agronomically promising new varieties of hard red winter wheat were extensively characterized in terms of their functional milling and baking properties. Functional properties of over 1,300 samples of early generation progenies of hard red winter wheat were determined. Polyacrylamide gel electrophoresis analysis to separate and identify wheat gliadins was standardized and adjusted to allow maximum resolution. An improved method for hydrolyzing and determining the amino acid compositions of pico-mole quantities of proteins in less than 3 hours was developed. Purothionin homologs have been isolated from *Aegilops squarrosa* and *Triticum uratu;* the purothionins were characterized by several methods. The results show that with regard to the gene(s) coding for purothionins, *T. urartu* has the genetic complement of the wheat A genome. The finding that purothionins may inhibit, in part, α-amylase activity may be important in the control of dormancy or sprouting-malting-germination in grain. A high-performance liquid chromatography method was developed to determine ascorbic acid in wheat flours, bread dough conditioners, and commercial tablets. We developed a simple, defined, highly reproducible, economical, and readily available medium to determine gas production as an index of yeast activity. We determined conditions for maintaining maximum viability of dry yeast in breadmaking. The type and amount of mixing and quantity of water were shown to affect inhibition of yeast activity by antimicrobial and antimycotic agents in wheat flour doughs and slurries.

We conducted a nationwide farm-bin survey for insects and fungi; it represents an unprecedented body of data detailing the pest populations in real world grain over a broad geographical area under a wide range of storage and management conditions.

Carboxylesterase-type malathion-specific resistance was found to be widespread and severe in populations of the Indian meal moth collected from grain bins on farms in nine midwestern states. Thirty-nine of 43 strains tested were more than seventeenfold resistant to malathion. This finding provides the first systematic documentation on a long-held suspicion and underscores the need to develop new means of moth control in stored grain.

In FY 1981 we initiated a small-bin field test to evaluate a new insect growth regulator (ethyl ρ-phenoxyphenoxyethylcarbamate) as a grain protectant.

An insulin-like peptide was purified from insect tissues, and its amino acid composition was determined. This is the firt time an insulin-like peptide has been isolated from an invertebrate species. A new catecholamine metabolite, *N*-β-alanyldopamine, was identified in insects. It is incorporated into cuticle during the process of sclerotization.

In FY 1981 we continued and expanded a pilot-testing program to develop practical methods for applying *Bacillus thuringiensis* to farm-stored grain and to demonstrate the treatment to farmers and state extension specialists. This research demonstrates our commitment to follow up promising laboratory studies on new pest control measures with tests to evaluate field performance and to integrate the procedures into grain management systems.

We have gained extensive basic knowledge of the insecticidal activity of *B. thuringiensis* through the development of a procedure for purifying the parasporal crystal. We used this procedure to characterize and compare the crystals of several subspecies. All produced a protoxin of ca. 1.34×10^5 molecular weight that converted to a toxin of ca. 6.5×10^4 molecular weight; however, subsp. *israelensis,* which is toxic to Diptera instead of Lepidoptera, also produced a unique peptide of ca. 26,000 molecular weight. We also developed serological techniques, including rocket immunoelectrophoresis and enzyme-linked immunospecific assay, that are more rapid and accurate than bioassay techniques for measuring crystal toxin. We completed an ultrastructural analysis and three-dimensional model of membrane development during *B. thuringiensis* sporulation. In conjunction with this membrane project, we studied the end-group mobility of iso-even branched-chain fatty acids in *B. thuringiensis* cytoplasmic membranes during growth and sporulation.

We have performed basic studies of the mechanism of infectivity of the granulosis virus (GV) of the Indian meal moth, *Plodia interpunctella.* Several subcomponents of the virus were isolated including enveloped and unenveloped nucleocapsids. From these subcomponents we extracted and characterized an internal core protein. We found similar proteins in other insect viruses. These proteins apparently stabilize the viral DNA. We examined the interaction between GV and vertebrate cells. The virus and subcomponents thereof, such as enveloped nucleocapsids, agglutinated rabbit erythrocytes. Although not infectious for the cells, GV does bind them. Enzyme studies indicated that GV interacts specifically with glycoproteins in the cell membrane.

Investigations on minimizing fuel energy required for grain drying included a study on farm-type, in-bin, grain-drying systems. Input electrical energy to complete drying was about the same for tests with and without solar heat. However, the average grain moisture content was one-half to one percentage point less with solar heat added. Electric power at rates of 3 to 5 watts per bushel starting volume was required by the drying fan motor. Total electricity input ranged from one-half to three-fourths kWh per bushel in batch corn tests.

Wind-powered grain aeration, as an alternative energy source for grain-storage bins located away from existing electrical lines, was studied. Harvesting wind power is neither inexpensive nor as simple as described by its proponents. In addition, enthusiasm cannot overcome the high initial cost of installation.

The emphasis of our research on the measurement and control of grain dust has shifted from determining grain dust characteristics to evaluating factors that affect dust emissions during grain handling. A field study was conducted in cooperation with the National Grain and Feed Association and the Ohio Farmers' Cooperative Association to determine the effectiveness of liquid additives in minimizing dust emission during grain handling. Spray applications of 0.04 to 0.1 percent by weight of deodorized vegetable oil or mineral oil were immediately effective in reducing dust emissions from corn, wheat, and soybeans. The effect of oil application increased as subsequent handling blended the grain during its passage through transfer operations.

We have developed a relatively simple and rapid method of measuring grain dustiness; the method involves sampling the dust cloud created by dropping a grain sample. Tests were conducted on about 3,000 corn and 5,000 wheat samples.

We participated in a round-robin series of tests on standard dusts in a project sponsored by the American Society of Testing Materials. The tests were conducted on a commercial 20-liter spherical vessel for which we developed the necessary instrumentation. Future dust explosion research in the United States and abroad likely will be conducted in 20-liter or larger vessels rather than in the previously used Hartmann bomb. Because of the high cost and experimental shortcomings of the commercial 20-liter vessel, we have developed a vessel that can be built at much less expense and which offers significant experimental advantages. To obtain better theoretical understanding of explosions in the 20-liter vessel, we have added instrumentation to measure light attenuation during dust dispersion, average flame speed, and product gas composition after the explosion.

We developed an operability study and a fault-free analysis of dust explosions in grain-handling facilities. A thorough analysis of the operation of a grain elevator was documented to determine the interrelationships between the failure of both man and machine and the occurrence of hazardous conditions in grain-handling facilities.

The value of our research depends on its acceptance by the target recipients. That acceptance involves an economic assessment of cost and impact. We are pleased to have the fine cooperation of the scientists from USDA's Economics and Statistics Service at USGMRL. Their continued evaluation of the economic feasibility of several of our programs adds an important dimension to our work.

The excellence of our scientists continues to be recognized by prestigious scientific awards from professional organizations, numerous invitations to present lectures, appointments to editorial boards, selections to organize national and international symposia and short courses, and appointments to act as scientific editors of prestigious series of advances. We are gratified by the great number of visitors to our laboratories. Distinguished visitors of varied scientific professions from 52 countries and from 33 states of the United States came to see our research facilities, to acquaint themselves with our activities, to share their thinking with us, and to consult with our scientists about novel approaches and new developments. Their stays ranged from a short visit to a year of research work. Those visits, along with innumerable requests for information, interviews, lectures, and participation on committees, acknowledge our diversified activities as the center of Grain Marketing Research.

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Published by
Agricultural Research Service
North Central Region
U.S. Department of Agriculture
Peoria, Illinois 61615

GRAIN STRUCTURE, COMPOSITION, AND CHARACTERIZATION UNIT

Scientists in this unit conduct investigations to (1) determine relation of grain structure to storage, handling, and utilization; (2) identify composition of cereal grains in relation to storage, handling, utilization, and nutritive value; (3) determine the use of enzymes in determining composition, structure, storability, and damage during handling of cereal grains; (4) develop tests on grain quality for use in plant-breeding programs, quality control during processing and storage, and action and regulatory agencies during marketing; and (5) identify, control, and eliminate mycotoxins from cereal grains.

Grain Structure

We study cereal grains and products of their processing by microscopic methods—light and scanning and transmission electron microscopy. These studies are designed to correlate grain structure with market quality investigations conducted in other research units in the Laboratory. Examples of studies in this area include comprehensive investigations on the structure of cereal grains, changes in the structure of dough and bread, structure of dough and bread from flours varying in breadmaking quality, and relation of grain structure to handling (corn breakage), storage (damage by molds and insects), end uses, nutritional value, and development of quality tests.

Grain Composition

In these studies, our approach is to determine protein, lipid, mineral, and carbohydrate contents and interaction products among grain components as they relate to storage, handling, utilization, and nutritional value. The studies are designed to provide information, on composition of cereal grains, to other units in the USGMRL in investigating the effects of composition on handling, storage, end uses, nutritional value, and development of quality tests. Examples of studies in this area include determination and characterization of lipids (including the role of lipids in breadmaking), interaction between lipids and proteins, and determination and characterization of proteins. The information has been used to develop nutritionally improved consumer-acceptable baked products.

Use of Enzymes

Enzymes are used to determine composition (proteins, carbohydrates, lipids, glycolipids, lipoproteins, and glycoproteins) and nutritional value of cereal grains, including availability of nutrients and their modification during handling, storage, and processing. Enzyme activity is assayed to determine grain quality at sprouting and deterioration during handling and storage. We design the studies to provide information on composition, as determined by enzymatic assays, and on levels of enzymes in cereal grains to other units at the Laboratory for determining soundness, characterization, and development of quality tests. Enzymes are used to determine, selectively and specifically, trace amounts of nutrients and contaminants in mold-, insect-, or rodent-infested grain.

Quality Tests

The information developed in the Grain Structure, Composition, and Characterization Unit and in other units at the USGMRL are used to develop tests for evaluating end use properties of new wheat cultivars, determining changes that occur during storage of grain, and evaluating grain in marketing channels. Examples include determining grain hardness in wheats from various classes, resilience of corn and susceptibility to breakage, degree of milling rice, and germinability of malting barley.

Mycotoxins

In mycotoxin research, we develop analytical procedures, preferably suitable for use in grain marketing channels, for detecting specific fungal components as measures of extent of invasion, mycotoxins, and other fungal metabolites, and for identifying fungi-grain interrelationships that may regulate invasion of particular grain types, varieties, or hybrids by specific genera or species of fungi. The approach used in these studies is to apply optimized extraction and chromatographic techniques and to simplify and make more effective initial extraction, cleanup, and final detection steps. Metabolites are evaluated as measures of fungal invasion on grains and are compared with mycological and other tests such as discoloration, germination, fat acidity, and odors. Differences in susceptibility to invasion by fungi among grain types, varieties, or hybrids, especially sorghum, also are investigated.

BIOLOGICAL RESEARCH UNIT

The Biological Research Unit is concerned with fundamental and applied biology of insects and microorganisms that infest stored grains and cereal products. Insects and microorganisms are the principal kinds of organisms that adversely affect grain quality. Insect and microbial activity in stored grains decrease germinability, discolor part or all of the seeds or kernels, cause weight loss, reduce nutritional value, produce heat, and increase moisture. The latter two factors, in turn, bring about physical, chemical, and physiological changes in the grain. Some insects feed on whole grain, others on broken kernels, thereby increasing the percentage of broken kernels and dockage. Some microorganisms produce toxins that are injurious to man and to domestic animals. Grain and cereal products are subject to insect and microbial infestation, damage, and contamination while in the marketing channels. The Federal Government, food storage, transportation, processing industries, and the consumer suffer large monetary losses from grain insects causing damage and downgrading and making the products unfit for human consumption. The presence of insects and the damage done by them affect us adversely in the highly competitive foreign market.

Another cause for concern in relation to foreign trade in grain is that pesticide and fumigant residues are receiving increasingly critical scrutiny in many parts of the world. These residues also are of concern for the domestic market. Urgently needed are more acceptable and effective methods for preventing insect damage and contamination during storage, handling, processing, packaging, transportation, and retail distribution. The need is critical for effective pesticides and application methods that can be used in our domestic and foreign markets without leaving objectionable residues. Even more desirable is the development of effective preventive and control measures using biological, physical, mechanical, or other nonchemical means that would reduce or completely eliminate the use of pesticidal chemicals.

The primary mission of the Biological Research Unit is to gain adequate knowledge of insects and microorganisms and their storage environment to develop appropriate techniques and methods of pest management under experimental and practical conditions. Research is divided into the following areas.

Pest Bionomics

Problems concerning the quality of grain in marketing channels are of concern to all segments of the grain industry. One of the detriments to quality is the level of insect infestation in grain. Research in this area characterizes insect activity by density, composition, and market location to provide a national overview of biological activity associated with grain during its storage and transport in the marketing system. These data help to identify problem areas where corrective actions are needed to maintain the quality of U.S. grain.

Insects in Export Grain.—A cooperative study by ARS, FGIS, and AMS was made to determine the incidence of insect infestation and fungal contamination in wheat and corn exported from the United States. Data were developed from more than 4,000 samples of wheat and corn loaded at 79 port terminals during the 2-year period from January 1977 to December 1978. *Sitophilus spp* (rice and maize weevils) and *Cryptolestes spp* (flat and rusty grain beetles) were the predominant inects found in both wheat and corn. Insects were detected most often in wheat from the Gulf and Great Lakes regions and in corn from the Great Lakes and Atlantic regions. The highest incidence of insects generally occurred in September and October.

Insects in Farm-Stored Grain.—An interagency study by ARS, ASCS, and FGIS was developed to provide basic information on insect activity in grain stored on the farm. More than 8,000 samples of wheat, corn, and oats from crop years 1976 through 1980 across 27 states were examined to determine the frequency, density, and composition of insect species infesting the grain. The occurrence and efficacy of pesticide treatments applied to the grain were also investigated. *Cryptolestes spp* were the most frequent pest in wheat, and corn and sawtoothed grain beetles were the predominant insect in oats.

Fumigation was reported in less than 10 percent of the wheat and oat bins and less than 5 percent of the corn bins. Malathion was used in only 15.2 percent of the wheat, 8.4 percent of the corn, and 5.4 percent of the oats, but when present it was generally effective in limiting both the incidence and density of insect populations, particularly in wheat. Malathion treatments were least effective against Indian meal moth and *Tribolium spp* in wheat and corn and against sawtoothed grain beetle in oats.

Biology and Control of Fungi

Research is directed toward increasing our understanding of molds or fungi that grow in and cause damage in grain. We monitor fungal population changes along with physical and chemical changes in grain during storage at various temperatures and

moistures. These studies include tests of grain during low temperature or solar-heated drying, as well as small bin and laboratory scale storage tests. Other variables being investigated are initial inoculum or mold spore load, storability differences among hybrids or varieties, and effects of mechanical damage. Preharvest fungal invasion of corn, as it affects quality and storability, is also studied.

Fungi in Farm-Stored and Export Grain.—Research during the past year has centered on an indepth study of fungal contamination in farm-stored and export grain. About 2,600 samples of corn, wheat, and oats taken from farm bins in ASCS's "Grain Reserve" program were tested for the presence of viable internal storage fungi. The grain was from crop years 1976-79, but there was little difference in fungal population that could be related to age. An exception was that 1979 crop grain had higher percentages of field fungi, which are known to gradually die during storage. The northern hard red spring wheat samples contained an average of 2.5 times as many storage fungi-invaded kernels as did the hard red winter samples. Corn from northern areas also tended to be moldier than corn from Kansas and Nebraska.

In the export survey, percentages of kernels containing viable storage fungi were about 10 times higher in corn than in wheat. *Aspergillus glaucus* was by far the most common storage mold. Corn samples from southeastern port locations had a higher incidence of *A. flavus* and of aflatoxin compared to corn from other regions.

Evaluating and Improving Chemical Pesticides

Research is directed toward establishing the effectiveness and stability of insecticides as grain protectants, bin treatments, and surface applications. Studies include the influence of biological, chemical, and physical factors on insecticide effectiveness, spectrum of activity, and residue stability. These studies specifically address the problems posed by decreased insecticide stability under high moisture and temperature conditions. We are developing effective and efficient procedures for integrating suitable materials into grain management systems, and the studies focus on specific infestation problems caused by changing grain harvest and such storage procedures as sanitation in and around grain drying equipment, insect control in larger storage facilities, and longer term storage. Tests are conducted in the laboratory in small bins, and in farm-type storage bins.

Candidate Grain Protectants.—Laboratory bioassays conducted over a 6-month period showed that permethrin was less effective than malathion. Propetamphos and M-9580 were more effective than malathion. Small bin studies were made with pirimiphos-methyl applied to corn, wheat, sorghum, rice, barley, and oats stored in seven States. Bioassays and infestation trends showed pirimiphos-methyl to be more effective than malathion.

Disinfestation of Bins with Drying Floors.—Several fumigants were evaluated for disinfesting the accumulation of grain dust and broken kernels beneath the perforated drying floor in bins. This debris can serve as a primary source of insects for infesting new grain. The tests were made in 3,000-bu (18-ft diameter) steel bins. Chloropicrin was effective when applied at the label dosage. Phosphine was effective at a dosage of 60, 1-g (actual phosphine) tablets/bin but only when confined by a polyethylene sheet over the perforated floor. However, phosphine is not currently labeled for this use. A liquid fumigant containing ethylene dibromide (EDB) was also effective when applied at a rate of 2 gal/bin. Liquid fumigants without EDB were not effective.

Fate and Metabolism of Stored-Grain Protectants

Research in this area is conducted to determine the influence of various physical and chemical factors on the metabolism of insecticides in stored grain. Information regarding the influence of such factors as temperature, moisture content, dockage content, and application uniformity would be helpful in predicting the behavior of insecticides in the field. The nature of insecticide metabolism, including production of insecticide metabolites, unextractable residues, and volatiles are investigated. Recent progress in this area includes the following:

Metabolism of Insecticides by Wheat Cultivers.—The metabolism of ^{14}C-malathion by four stored wheat cultivars was investigated. Preliminary results indicated that cultivars may differ significantly in their ability to metabolize ^{14}C-malathion. All cultivars contained larger quantities of unextractable residues after 21 days than immediately after treatment.

Insecticide Resistance in Insect Pests of Stored Grain

Research in the insecticide toxicology laboratory is designed to (1) monitor the extent and severity of insect resistance to insecticides currently in use on stored grain in the United States, (2) assess cross-resistance to candidate grain protectants with potential for registra-

tion and future use, (3) elucidate biochemical and genetic mechanisms for the most prevalent type(s) of insecticide resistance, (4) screen novel classes of chemicals to reveal new types of candidate grain protectants, and (5) analyze pest insect-host grain interactions that may confer tolerance to insecticide treatments.

Survey of Malathion Resistance in Insect Pests of Stored Grain in the United States.—Forty-three strains of the Indian meal moth were collected from grain bins on farms in nine midwestern states. Thirty-nine of the 43 strains were more than seventeenfold resistant to malathion. None of 10 resistant strains tested were cross-resistant to chlorpyrifos methyl. Of seven resistant strains assayed for malathion carboxylesterase activity, all had greatly elevated levels over those of a susceptible strain. The α-monoacid of malathion was the major hydrolysis product in all six resistant strains. When esterase electrophoretograms were prepared of 16 strains ranging from purely susceptible to purely resistant, a good correlation was observed between resistance level and the staining intensity of certain esterase bands. We conclude that carboxylesterase-type malathion-specific resistance is epidemic in Indian meal moth populations throughout the U.S. grain belt.

Similar studies on the incidence and physiological nature of malathion resistance have been initiated for approximately 50 strains of the red flour beetle (*Tribolium castaneum*), rice weevil (*Sitophilus spp*), and lesser grain borer isolated from grain samples from farms in 14 States.

Biochemical and Genetic Analysis of Malathion Resistance in the Indian Meal Moth.—Studies initiated in 1980 were refined and extended. Severe malathion resistance in a strain of the Indian meal moth was highly specific for malathion and was suppressed by nontoxic carboxylesterase inhibitors. Fifth instars of the resistant strain had 33 times as much malathion carboxylesterase activity but only 0.64 times as much α-naphthyl acetate esterase activity as larvae of a susceptible strain. Resistance was controlled by a single autosomal gene or closely linked set of genes. Resistance and malathion carboxylesterase were inherited as completely dominant and semidominant factors, respectively, and were genetically linked. α-Naphthyl acetate esterase isozymes resolved by electrophoresis revealed eight interstrain differences, at least four of which were semidominant. Two of the four semidominant isozymes were clearly associated with resistance to malathion. Similar investigations have been initiated for strains of the red flour beetle.

Microbiology of Insect Pathogens

Many insect pests that infest stored grain and processed cereal products are susceptible to microbial insect pathogens such as certain bacteria, viruses, and fungi. These microorganisms are selective in their insect pathogenicity, do not pollute the environment, and are not harmful to man or other mammals. Our research with these organisms involves basic and applied studies of the structure, physiology, and mode of action of selected bacterial and viral insect pathogens. These studies include the use of *Bacillus thuringiensis* and granulosis virus to control the Indian meal moth and other Lepidopteran pests of stored grains; structure, toxicity, and biosynthesis of the entomocidal protein of *B. thuringiensis;* use of insect tissue culture for *in vitro* determination of molecular toxicity; and measurement of differential toxicity between various *B. thuringiensis* isolates. Recent progress in this area includes the following:

Biochemistry of Entomocidal Protein from *B. thuringiensis*.—A procedure for purifying the entomocidal protein of *B. thuringiensis* subsp. *kurstaki* was established and used to determine certain biochemical and biophysical properties. The alkali-solubilized protoxin was found to have an apparent molecular weight of 1.34×10^5. The only NH_2-terminal residue found was methionine. The soluble protoxin was 2.5 times more toxic to insect larvae than was the parasporal crystal. At alkaline pH, the protein protoxin slowly converted to a low molecular weight toxin (apparent $M_r = 6.8 \times 10^4$). The molar specific toxicities of the protoxin and toxin were identical.

The parasporal crystals of several different serotypes of *B. thuringiensis* were compared by electron microscopy, polyacrylamide gel electrophoresis, amino acid analysis, tryptic peptide mapping, immunological analysis, and insecticidal activity. Four of the strains investigated produced crystals that were toxic to Lepidopteran insects; the other *B. thuringiensis* subsp. *israelensis,* was toxic for Diptera. All species produced a protoxin of approximately 1.34×10^5 molecular weight. However, *B. thuringiensis* subsp. *israelensis* inclusion bodies contained a unique peptide of approximately 26,000 molecular weight, which was absent in the other subspecies.

Alternative Bioassay Technique for Measurement of *B. thuringiensis* Parasporal Protein.—Rocket immunoelectrophoresis can be used as an alternative to insect bioassay of *B. thuringiensis* entomocidal protein. The immunoelectrophoretic technique was rapid, specific, and accurate; it could be used to measure crystal toxin on commercial microbial insec-

ticides that contain a mixture of spores, vegetative cells, and carrier materials. Maximal synthesis of crystal antigen occurred between t_3 and t_6 of sporulation. The appearance of completed spores within the mother cell followed synthesis of the crystal toxin. Vegetative cells and early stationary-phase cells did not produce antigen, and they were not toxic to insects.

Characterization of the Granulosis Virus of the Indian Meal Moth.—The first step in the infection process of the Indian meal moth with granulosis virus (GV) is adsorption of the virion to the membrane of the host cell. Unfortunately, GV as a group does not appear to infect insect cells *in vitro,* and no suitable tissue culture system has yet been found to support their replication. Consequently, we have studied the conditions and mechanism of viral adsorption using an artificial model system. The model involved the hemagglutination of vertebrate erythrocytes by GV. Agglutination occurred at acidic pH, and the phenomenon was enhanced by aggregation of the enveloped nucleocapsids. However, radioisotope studies indicated that binding (adsorption) also occurred under alkaline conditions, although hemagglutination was not observed.

Ultrastructure of *B. thuringiensis*.—The development of forespore membrane in *B. thuringiensis* subsp. *kurstaki* was studied by use of freeze-fracturing and serial-sectioning techniques. Vesicular mesosomes were associated with the initiation and development of the forespore septum. Upon completion of the septum, engulfment of the incipient forespore commenced. The engulfment membranes always maintained an orientation consistent with that of the plasma membrane when viewed with freeze fracture. Forespore development was complete when the forespore membranes detached from the plasma membrane and transformed into the inner and outer forespore membranes.

Integrating Microbial Insecticides into Grain Protection Programs

Research in this area is directed toward developing methods for using microbial insect pathogens to prevent and control insect infestations in stored grains and processed products. Included are studies of the susceptibility of populations of Indian meal moths and almond moths to *B. thuringiensis,* evaluation of the effects of commodity characteristics, storage environment, and types of storage systems on pathogen persistence and effectiveness, and studies of interactions between biology and behavior of the pest insect species and method of pathogen application. Recent progress in this area includes the following.

Pilot-Testing Methods of Applying *B. thuringiensis* to Grain.—A 3-year pilot-testing program to evaluate the performance of *B. thuringiensis* under farm grain bin conditions in Nebraska, Kansas, Oklahoma, Iowa, and Illinois is in progress. This study includes comparisons of the efficacy of dust and wettable powder formulations, the relative effectiveness of different water volumes for applying the wettable powder, and application in the auger at the time bins are filled versus application to the grain surface after the bins are filled. The uniformity, toxicity, and long-term performance of the bacterial deposits produced by the various treatment methods are being evaluated. We are also measuring the *B. thuringiensis* susceptibility of field populations of Indian meal moths. Conclusive data are not yet available, but the tests are to be continued for another year.

Spores in Dockage and Mill Fractions of Wheat Treated with *B. thuringiensis*.—Dockage fractions of wheat treated with *B. thuringiensis* Berliner contained more spores than whole wheat, but 75 to 85 percent of the spores remained on the wheat after cleaning. Tempering of the wheat prior to milling reduced viable spore counts by half. More spores were present on the outside layers of the wheat kernels than in the flour. Flour contained 1 to 5 percent of the initial number of spores, and bread baked from it contained few or no viable spores.

The *B. thuringiensis* content of the flour was too low to cause appreciable mortality among 3rd or later instars of the Indian meal moth or the almond moth, except when flour was produced from unblended treated wheat. Flour absorptions, bake mixing times, mixogram mixing times, other physical properties of the dough, and bread loaf volumes of flours from treated wheat were essentially the same for the controls. Thus, the *B. thuringiensis* treatments had no effect on the baking quality of flour from treated wheat.

Compatibility of *B. thuringiensis* and Captan.—Laboratory studies showed that *B. thuringiensis* can be mixed with Captan seed treatment and applied to seed without detrimental effects on either spore viability or insecticidal activity of *B. thuringiensis*. Thus, *B. thuringiensis* should be useful for protecting crop seed from moth infestation.

Insect Biochemistry and Physiology

Our goal is to understand the growth and development of insects of biochemical terms and to identify metabolic processes that are potential targets for new

pest control agents. The program includes basic research in insect biochemistry, endocrinology, toxicology and morphology, and applied research in the development of biorational materials that inhibit specific aspects of the insect's physiological and behavioral development. Chemicals receiving special attention are insect growth regulators that act as hormone mimics or antihormones and compounds that disrupt cuticle biochemistry.

Pridyl Ether Analogs of Juvenile Hormone Synthesized and Used for Suppression of Stored-Grain Insect Progeny.—We continued testing juvenile hormone analogs for activity against stored-grain insects. Compounds with long alkyl side chains were the most active, preventing development of adult progeny when applied to grain at ppb levels in the laboratory.

Regulatory Mechanism for Pyruvate Metabolism in Insects Determined.—The pyruvate dehydrogenase multienzyme complex (PDC) catalyzes the oxidation of pyruvate to acetyl CoA. This irreversible reaction results in a net loss of body carbohydrate. Thus, regulation of this step is of central importance to the general energy balance and fuel economy of animal cells. We determined how this reaction is regulated in insect tissue. Fat body PDC undergoes interconversion between an active, nonphosphorylated form and an inactive, phosphorylated form. Nutritional state, metabolite levels, and neuroendocrine factors modulate the interconversion.

Tyrosine Metabolites Identified That Participate in Insect Cuticle Sclerotization.—*β-D*-Glucopyranosyl-*O-L*-tyrosine was found to be the major tyrosine storage metabolite for production of tanning diphenol substrates in more than 20 species of Lepidoptera. Tyrosine was hydroxylated and decarboxylated to dihydroxyphenylalanine and 2-(dihydroxyphenyl) ethylamine during pupal sclerotization.

A Glucagon-Like Peptide Found in Insect Gut Tissue.—We continued our search for vertebrate hormone-like substances in insects. A glucagon-like peptide was detected in extracts of insect midgut. The molecular weight was approximately 15,000. It was concluded that the insect gut, like its mammalian counterpart, contains a large glucagon-like peptide that shows highly selective immunoreactivity.

Ascorbic Acid Sequestered in Many Insect Tissues.—Ascorbic acid is an essential vitamin for many species of insects. We determined its distribution and titer in various tissues and looked for the presence of biosynthetic enzymes. Ascorbic acid was found in eggs, labial gland, hemolymph, gut, muscle, cuticle, nervous tissue, and gonads at concentrations ranging from <10 to >150 mg/100-g wet weight. No *L-gulonolactone* oxidase was detected in tissue extracts.

Insect Cell Lines Secrete Molting Enzymes.—We developed *in vitro* techniques to determine how molting enzymes are regulated. Media from several insect cell lines exhibited *β-N*-acetylhexosaminidase and chitinase activities. No changes in enzyme levels were observed when cells were incubated with molting hormone or juvenile hormone. One enzyme fraction was purified and characterized.

Entomocidal Protoxins of *B. thuringiensis* Purified and Characterized.—We developed a procedure for purifying the protoxin and determined its biochemical and biophysical properties to determine how the entomocidal crystal of *B. thuringiensis* kills insects. At alkaline pH, the protoxin (apparent M_r = 1.34×10^5) slowly converted to a toxin ($M_r = 6.8 \times 10^4$). Crystals of various subspecies were compared by electron microscopy, gel electrophoresis, amino acid analysis, peptide mapping, immunological analysis, and insecticidal activity.

Phosphorus Metabolites in Insect Hemolymph Identified by Nuclear Magnetic Resonance.—We began a study of phosphorus metabolism during insect development using NMR spectroscopy. The phosphometabolites found at millimolar or higher concentrations in larval hemolymph were α-glycerolphosphate, phosphorylcholine, phosphorylethanolamine, inorganic phosphate, trehalose-6-phosphate, phosphatidylcholine, and phosphatidylethanolamine. All above were also found in pupal sera, except for the addition of phosphoarginine and the deletion of phosphorylethanolamine.

Grain Resistance to Storage Insects

In resistance research we develop procedures to determine grains that exhibit preference, antibiosis, and tolerance to insects. The approach in these studies is to determine the relative resistance or susceptibility of currently grown and newly developed cultivars to attack by stored product insects. For resistant or highly susceptible grains, efforts are made to determine the causes of resistance of susceptibility. Examples of recent progress in these studies include the following:

Role of Kernel Coating and Bran Layers in Resistance of Wheat to Rice Weevils.—Grains of five wheat cultivars were tested as whole, peeled, and pearled grains for differences in rice weevil production. Newton variety produced the greatest number of progeny of the five cultivars where peeled and pearled grains were used.

Studies on Barley Resistance.—Grains of several barleys, grown at different locations and stored for several years under laboratory conditions, were tested for rice weevil resistance as influenced by production location, aleurone layer, and protein levels. Significant differences were seen in levels of progeny production by barleys from different locations; some varietal differences were indicated.

Grain Dust Production by Insects

Studies are conducted in conjunction with the Engineering Research Unit on the production of dust by stored-grain insects. The studies are designed to characterize dust produced by the major stored-grain insects as to particle size, quantity, composition, and explosibility. The manner in which the insects produce this dust as a part of their feeding is also studied.

Grain Dust Production by Flour Beetles.—Flour beetles, caged on whole grains, were found to produce heavy amounts of dust. This dust was in the very small size range ($<0.05\mu$) like dust produced by rice weevils, and was visually indistinguishable from grain dust produced by abrasion. Considerable kernel destruction, as a result of adult feeding, was also noted.

ENGINEERING RESEARCH UNIT

Researchers in the Engineering Research Unit conduct investigations to (1) minimize fuel energy required for grain drying, (2) measure and control dust from grain handling, and (3) reduce damage to grain from handling. Recent progress in these areas of research is summarized as follows.

Minimizing Fuel Energy Required for Grain Drying

The efficiency of grain drying was studied in farm-type in-bin grain-drying systems. Efficient in-bin drying required consideration of airflow rate, electric energy input, and acceptable risk of mold growth or spoilage. The combination of solar heat and natural air in-bin grain drying conserved energy and improved grain quality for storage and marketing. Quality of high-moisture corn and grain sorghum was maintained during drying with air temperatures 2° to 5° C above ambient air. Corn graded No. 1 for bin lots below 14 percent moisture and No. 2 for the lots between 14 and 15.5 percent moisture. The sorghum bin lots were dried during cold weather with drying fans operated only 8 to 12 h during the daytime. The daytime operation dried sorghum to below 14 percent moisture and made use of higher ambient air temperatures and solar heat when available.

Air-heating solar collector units with aperature areas equal to drying bin floor areas provided adequate heat to the ambient air to reduce the grain moisture to safe storage or marketing grades or both. Solar energy contributed about 10 percent of the heat-drying potential. The fan and motor heat contributed another 10 percent of the heat for moisture removal. About 80 percent of the heat for drying was supplied by the atmospheric air. Comparable natural air in-bin grain-drying systems reduced moisture content to about 15 percent with corn in concurrent test periods and continuous fan operation. Heat for drying in the natural air system was about 25 percent from electrical energy supplied by the fan motor unit and 75 percent from ambient air to the fan.

For drying at several airflow rates, in-bin grain depths were tested. High airflow rates with 22 to 24 percent moisture corn, about 7 ft deep in September, moved the drying front through the surface in 5 days. Drying was completed in 4 to 5 days for corn with moisture content below 20 percent loaded to about 8 ft deep. The airflow rates produced an air velocity through the grain of 25 to 30 ft/min/ft² of floor area.

Input electrical energy was about the same for drying corn with and without solar heat. However, the average grain moisture content was one-half to one percentage point less with solar heat added. The drying fan motor required 3 to 5 watts/bu starting volume. Total electric input ranged from one-half to three-fourths kWh/bu in the batch corn tests.

Resistance to airflow pressure supplied by the fan was measured every hour during 5-day drying periods for yellow corn at bin-loading depths of 6-1/2 to 7-1/2 ft in an indoor 21-ft diameter bin. Airflow velocities were from 27 to 29 ft/min/ft² of bin floor area. There was no measurable increase in resistance to airflow during the first days of operation with 23 to 24 percent moisture corn. This was followed by a small decrease in resistance as the grain bed depth decreased and grain moisture was reduced.

We cooperated with the scientists in the Biological and Grain Structure, Composition, and Characterization Research Units in a study of mold growth in a 100-bu corn bin. A graphical method was developed to determine the combined effects of time, temperature, and mold concentration on the overall production of CO_2. This method allowed comparison to be made between laboratory and pilot scale test data.

Wind-powered grain aeration was studied to evaluate the performance of a propeller type and a turbine type air-exhausting machine. Wind-powered grain aeration may offer a realistic, alternative, energy source for a bin located away from existing electric lines. However, harvesting wind power is expensive; the initial cost may exceed that of electric fans.

A propeller type air-exhaust machine with a 4-in inside diameter pipe was installed for a 15-ft diameter grain bin filled with 700 bu of sorghum about 4 ft deep. This machine produced a negative pressure in the support pipe airduct of 25 to 50 pascals when wind velocities were 3 to 4 m/s and about 250 pascals for 9 m/s wind velocity. Calculated airflow rates were from 25 to 75 cfm or 0.05 to 0.10 cfm/bu of sorghum. Controlling insect growth by quickly cooling sorghum grain with the aerator was ineffective.

Measuring and Controling Dust Generated from Grain Handling

The research emphasis shifted from determining grain dust characteristics to evaluating factors that affect dust emissions during grain handling.

A field study was conducted in cooperation with the National Grain and Feed Association and the Ohio Farmers' Cooperative Association to determine the effectiveness of liquid additives in minimizing dust emissions during grain handling. Spray applications of 0.04 to 0.10 percent by weight of deodorized vegetable oil or mineral oil were immediately effective in reducing dust emission from corn, wheat, and soybeans. The effect of the oil application increased as subsequent handling blended the grain during passage through the transfer operation. Mineral oil treatment retained effectiveness during a second handling after 3 months of storage. Spraying corn with 0.15 to 0.33 percent water was temporarily effective. None of the liquid treatments were as effective in controlling airborne dust concentrations as was the conventional dust control system.

Grain dustiness was measured in about 3,000 corn and 5,000 wheat samples of farm-stored grain. The analysis of the data is in progress.

A light extinction method was used to determine particle size and concentration of suspended grain dust. *In situ* data were compared to Hi-Vol sampling and sedimentation analysis methods. Data included results from dust generated during corn and wheat handling at two flow rates.

Rheological properties of grain dust were measured to determine compression creep and stress relaxation properties, degree of elasticity, hysteresis loss, and the pressure-density relationship of wheat dust, grain sorghum dust, and corn dust at room temperature. The measurements were conducted by a Dillon Testing Machine and an in-house developed compression apparatus. Bulk densities of grain dust ranged from 180 to 350 kg/m^3 at loosefill conditions and from 400 to 660 kg/m^3 at a pressure of 120 kPa. A functional relationship expressing bulk density of grain dust as a function of pressure was obtained. The compression creep and stress relaxation properties of grain dust can be described by Burger's model and the generalized Maxwell model represented by three Maxwell elements, respectively. In compression creep tests, we found that the higher the moisture content of grain dust the greater the amount of retarded elastic strain. In stress relaxation tests, moisture content had a significant effect on decay modulus. The degree of elasticity of grain dust ranged from 10 to 50 percent, depending on moisture content and type of dust. The degree of elasticity decreased as moisture content increased. The hysteresis loss of grain dust during loading and unloading cycles ranged from 70 to 80 percent and increased slightly with increasing moisture content.

A furnace designed to burn grain dust and produce energy for space heating of crop drying was developed. The furnace was tested with capacity and performance of wheat, grain sorghum, and corn dust. The dust-burning (feeding) rate of the furnace ranged from 4 to 10 kg/h. The output capacity from the heat exchanger ranged from 11 to 16 kW. The efficiency of the furnace ranged from 37 to 61 percent depending on the burning rate. The efficiency decreased as the burning rate increased. The air temperature from the heat exchanger ranged from 124° to 182° C, depending on the dust-burning rate.

The destructive power of a grain dust explosion depends on the maximum pressure, P_{max}, and maximum rate of pressure rise, $(dP/dt)_{max}$. To relate laboratory measurements of these quantities to the real world, one must measure P_{max} and $(dP/dt)_{max}$ in a vessel large enough to permit extrapolation to volume of interest. Research has shown that a 20-liter spherical vessel is large enough to permit extrapolations to larger volumes using an empirical scaling law. We developed the instrumentation for a commercial vessel and participated in a round-robin series of tests on standard dusts in a project sponsored by the American Society for Testing and Materials. The results of our initial series of tests were consistent with the results of most of the other participating laboratories. Future dust explosion research in the United States likely will be conducted in 20-liter or larger vessels rather than in

the previously used Hartmann bomb. Gas-sampling equipment was added to the 20-liter vessel for analysis of the post combustion gases. A series of tests determined the fraction of dust that is suspended in the dust cloud in the vessel at the time of ignition. A significant portion of the dust loaded into the vessel was not suspended in the chamber but was trapped in the dispersion pipes. By carefully measuring the mass of dust within the pipes after the dust was dispersed, a much better estimate of the dust cloud concentration at the time of ignition was obtained.

Because of the expense and experimental shortcomings of the commercial apparatus, a 20-liter explosion vessel, which can be built at much less expense and which offers significant experimental advantages, was designed and constructed. The newly developed 20-liter explosion vessel shares some of the instrumentation used with the commercial vessel.

Work is underway to obtain better experimental and theoretical understanding of an explosion in the 20-liter vessel. To this end, we have added instrumentation to measure light attenuation during dust dispersion, average flame speed, and product gas composition after the explosion. A theoretical burn model is being formulated to explain the experimental results. The theoretical analysis of the dust explosion in the 20-liter bomb has been approached in two ways. An ordinary differential equation solution (lumped parameter model) was developed. It gives a reasonably accurate prediction of the pressure development in the bomb but does not correctly predict the radial variations of temperature and dust concentration during the explosion. A second, hopefully more realistic approach, is now being developed. It consists of a set of partial differential equations that describe the change in composition, temperature, and pressure within the bomb. This model will include conductive, convective, and radiative heat transfer within the reacting dust cloud. Radial variations in composition and temperature will also be included.

An operability study and a fault-free analysis of dust explosion in grain-handling facilities were developed. A thorough analysis of the operation of a grain elevator was documented to determine the interrelationships between the failure of both man and machine and the occurrence of hazardous conditions in grain-handling facilities.

Reducing Damage to Grain from Handling

We studied the bulk properties of grain as affected by self-propelled, rotational type, grain spreaders. The performance of the four-trough self-propelled rotational grain spreader (the in-house developed spreader) was evaluated for wheat, corn, and grain sorghum under conditions of choke-feeding grain to the spreader. The flow rate of grain was about 1,200 bu/h. Two commercially available rotational type of grain spreaders were also tested for comparison of performance. Parameters evaluated included (1) effectiveness of spreader in producing a level surface with a uniform distribution of fine material within the grain mass, (2) bulk density and airflow resistance of grain in the bin, (3) distribution of static pressures in the grain mass, and (4) dustiness of air inside the bin during filling.

Instrumentation was developed to measure grain velocity, one of the variables affecting grain dust emissions and grain breakage. Three devices were developed: (1) An inexpensive and simple probe was constructed for use in velocity measurements based on the correlation technique. It consisted of two light-emitting diodes and two phototransisters that produced a pair of signals for autocorrelating. (2) An axial flow-rotating vane of rugged design was constructed. This device, when calibrated, used the momentum of the grain to determine velocity. (3) Another rotating vane used grain momentum applied as a tangential force to turn the wheel. This device also required calibration for determining grain velocity. A high-speed camera will be used to calibrate the measurements.

Computer Facilities

The computer facilities provide a multitude of services to all researchers at USGMRL. The present computer facilities include one old and one new minicomputer with three terminals. The old minicomputer is used to gather data from nonstandard peripheral devices and to input data from standard devices such as punch paper tapes and keyboards. Interface hardware for nonstandard devices was designed and built at the facility. Assembly level software was also written to drive the nonstandard devices under the operating system. The new minicomputer is used primarily for statistical analysis and data manipulations requiring a large amount of storage space. Both computers have extensive, in-house developed, graphical capabilities that are used by the laboratory researchers. Extensive programs have been written for various personnel at the laboratory, and programming assistance is available to individual researchers. Although all laboratory units have active computer programs, expansion of magnetic tapes and more terminals are planned to serve the increased use.

GRAIN QUALITY AND END-USE PROPERTIES UNIT

Research activities in the Grain Quality and End-use Properties Unit are concerned with (1) identifying physical and structural characteristics and chemical components that govern or are associated with functional properties; (2) developing, improving, and evaluating methods and instruments that can be used to objectively, rapidly, and accurately characterize and evaluate grain in domestic and export marketing channels; and (3) cooperating with plant breeders throughout the Great Plains and with agronomists, plant physiologists, entomologists, and biochemists at Kansas State University by providing milling, baking, and biochemical expertise and support for selective projects of mutual interest.

Specifically, researchers (a) Determine and evaluate the functional (milling and breadmaking) properties of early generation and potentially new hard winter wheats bred for the Great Plains and evaluate the earliest feasible generation of hard winter wheats bred for genetically high-protein content. Kjeldahl (protein) analytical equipment and the 10-g mixograph, together with micro- and macro-milling and breadmaking equipment, are employed to determine functional properties of about 1,600 plant breeders' samples (10 to 1,500 g); (b) Develop new methods and techniques of determining chemical, milling, breadmaking, physical-chemical, and biochemical properties of hard wheats; (c) Develop energy-conserving baking methods and high-protein and nutritionally improved breads, and (d) Develop physical and biochemical fractionating and reconstituting techniques to relate functional (breadmaking) to biochemical properties of wheat-flour components and determine the chemical fractions and components of wheat responsible for quality differences.

After literally taking the flours apart, corresponding gluten-protein, gliadin- and glutenin-protein and their fractions, modified and unmodified, and other wheat flour fractions of good and poor quality wheat flours are interchanged, one at a time and in combinations, in the reconstituted flours. Fractions and reconstituted flours are characterized by physical, biochemical, and breadmaking techniques. Research during the past year has been in the following areas.

Determining and Evaluating Functional Properties of Potentially New Hard Winter Wheats

About 286 samples, each about 1,500 g, of agronomically promising new varieties and recent releases of hard winter wheat were characterized and evaluated in terms of their functional properties including wheat hardness; bolting properties and flour yield; flour ash; dough mixing, oxidation, and water requirements; bread crumb grain and color scores; and loaf-volume potential. About 37 percent of the samples had good milling, chemical, breadmaking, and physical dough properties. Leading commercial wheat varieties of tomorrow are among them, and a number of progenies, in addition, had genetically high protein contents.

About 1,316 small samples (40 to 100 g) of early generation progenies of hard winter wheats were micro-milled and evaluated for milling. We subjected each sample of flour to certain analytical, water-absorption, and mixogram tests. About 538 (41 pct) had promising overall functional properties. Also, 484 of the 538 promising ones had 1 to 5.2 percentage points and 95 had 2.5 to 5.2 percentage points more flour protein than their controls.

From 1975-81, average wheat yield in Kansas (30.6 bu) was 6.4 bu greater, and average wheat protein content (12.2 pct) was 0.5 percent higher than the corresponding averages for the 1960's. Thus, the gradual decline in wheat protein content apparently has been halted and reversed during the past 7 years by high protein "Eagle" and other relatively new Kansas varieties of hard winter wheat. Furthermore, during the 5 years 1977-81, average wheat yield in Kansas (31.1 bu) was 14 bu greater than and average wheat protein content (12.4 pct) was equal to the corresponding averages for 1948-59. Without the new varieties of the 1970's, wheat protein content probably would have continued to decrease to about 11 percent.

Improved Method for Standardizing Polyacrylamide Gel Electrophoresis of Wheat Gliadin Proteins

Many laboratories around the world have used polyacrylamide gel electrophoresis (PAGE) analysis to separate and identify wheat gliadins, but different methodologies used by different groups precluded direct comparisons of results. We developed a standardized method for PAGE analysis of wheat gliadin extracts. Commercially available equipment and reagents were used. The purity and concentration of aluminum lactate, the type of gel former, and the method of gel preparation are variables that can affect PAGE results. The standardized method should reduce the deleterious effects of the variables and enhance the day-to-day reproducibility of gliadin separations. The method has been adjusted to allow maximum resolution of the gliadin protein bands.

Identifying Wheat Cultivars by Gliadin Electrophoresis: Electrophoregrams of the 88 Wheat Cultivars Most Commonly Grown in the United States in 1979

The PAGE patterns (electrophoregrams) of the gliadins from 88 U.S. wheat cultivars have been determined and catalogued. The cultivars examined were those grown on the largest acreages—each cultivar on 130,000 acres (0.2 pct of the total U.S. wheat acreage) or more—in 1979. The 88 cultivars examined comprised 89.3 percent of the 1979 acreage. The following classes and numbers of wheats were investigated: 37 hard red winter, 17 hard red spring, 12 soft red winter, 14 common white, 1 white club, and 7 durum. Most of the cultivars were readily differentiated by their electrophoregrams. Some very closely related cultivars gave identical gliadin electrophoretic patterns and were thus not uniquely identifiable by PAGE.

Gliadin Protein Composition of Triticales and Their Wheat and Rye Parents

PAGE patterns were compared among gliadin proteins extracted from two newly synthesized (by CIMMYT, Mexico) hexaploid triticales (Yemen-Snoopy and Chapala-Snoopy), their parents, a stable triticale (Bacum), and a wheat (Inia 66). PAGE patterns were identical for gliadin proteins extracted from either whole grain flours or the milled starchy endosperm flours of the triticales, the wheats, and the rye. There were differences, in some protein components, among triticales and among wheats. The inheritable or deviating trends in certain components of triticale gliadin proteins are of particular interest.

Method for Hydrolyzing and Determining the Amino Acid Compositions of Pico-Mole Quantities of Proteins in Less than 3 Hours

A method was developed for quantitatively hydrolyzing proteins in 45 min and for analyzing the hydrolysates by high performance liquid chromatography (HPLC) in 45 min. The amino acids were detected by the fluorescence of their *O*-phthaldialdehyde derivatives. Ten pico moles of each of the commonly occurring α-amino acids can be reliably determined. The HPLC method provides a better separation of amino acids than previously published methods.

Studies of Purothionin Homologs from Two Diploid Wheat Relatives

Purothionin homologs have been isolated from *Aegilops squarrosa* and *Triticum urartu*. Tryptic and chymotryptic peptides from those proteins have been separated by HPLC, and the amino acid compositions of the peptides were determined by an HPLC microanalytical method developed in this laboratory. By comparing the HPLC peptide elution patterns and the amino acid compositions of the peptides from the *Ae. squarrosa* and *T. urartu* with those from α_1-, α_2-, and β-purothionins from bread wheat, we found that the proteins from *Ae. squarrosa* and from *T. urartu* were very similar or identical with the α_2- and β-purothionins, respectively. This work confirms our previous postulate that the diploid species donating the D genome to bread wheat should contain a protein like α_2-purothionin. *T. urartu* has at different times been proposed as being the donor of either the A or B genone to polyploid wheats. *T. urartu* contains β-purothionin, which we have already shown to be coded by part of the A genome. It is thus apparent that, with respect to the gene(s) coding for purothionins, *T. urartu* has the genetic complement of the wheat A genome and so is unlikely to have donated the wheat B genome.

Inactivating α-Amylase Activity by Purothionins

We found that α_1-purothionin inhibited 45 percent of the amylase activity and that β-purothionin inhibited 39 percent of the activity. When calcium chloride (10^{-5} mole) was included in the inhibition-incubation mixture containing β-purothionin, there was no inhibition of the amylase activity. In the absence of calcium chloride, inhibition occurred as before (34 pct). Addition of calcium chloride to an enzyme assay without inhibitor resulted in no augmentation of activity, indicating that calcium was not a limiting factor in the enzyme assay. We concluded that purothionins can inhibit the activity of wheat α-amylase under the conditions of the assay and that they possibly act by controlling the availability of calcium to serve as a cofactor. This may be important in the control of dormancy of germination in grain.

Determining Ascorbic Acid in Wheat Flours, Bread Dough Conditioners, and Commercial Vitamin C Tablets by HPLC

An HPLC method was developed to determine ascorbic acid (vitamin C) in wheat flours, bread dough conditioners, and commercial vitamin C tablets. Dithiothreitol (0.7 mM) stabilized vitamin C without reducing extraction efficiency. Extraction and analysis were complete in less than 30 min. Extraction efficiencies were 73 to 78 percent for the flours and 100 percent for the dough conditioners and vitamin C tablets.

The method is over 1,000 times more sensitive than the Association of Official Analytical Chemists method (10 ng vs 50 μg) and is not adversely affected by some metal ions and basic compounds. Vitamin C contents of dough conditioners were found to be higher than the labeled potency. Over-the-counter vitamin C tablets, stored in capped vials for various periods of time at room temperature, had a shelf life of at least 14 years.

Defined and Reproducible Gas Production Medium

Several factors can cause errors in determining gas production as an index of yeast activity. We developed a simple, defined, highly reproducible, economical, and readily available medium that contains either one of two water soluble gums, guar, and xanthan. The gum absorbs large amounts of water and forms a gel-like medium that holds all ingredients in suspension to facilitate uniform gas production. The guar-containing gassing medium contains a solution of $(NH_4)_2HPO_4$ (37.7 mg/test) and provides sufficient nitrogen (8 mg) and phosphorus (8.7 mg) for nearly optimal gas production and is economical and efficient to prepare. The ratio of phosphorus to nitrogen should be about 1:1. At optimum concentration of gum, gas production in guar gel was about three gasograph units more than in xanthan gel. Guar gum (1 g) presently is preferred because it is less expensive, more readily available, and gives somewhat higher gas production than xanthan gum.

Functional (Breadmaking) Properties of a New Dry Yeast

Eight vacuum- and two nonvacuum-packed dry yeasts had excellent viability when opened 4 to 22 months after being manufactured. Dry yeast maintained good viability after being opened 48 times over a period of 18 weeks when properly sealed and stored. Some methods of adding dry yeast should be avoided. For example, gas production of dry yeast decreased with increasing time in contact with wheat flour at room temperature; the decrease was more than 22 percent in 18 h. Rehydration of dry yeast in distilled water decreased yeast viability more than did rehydration in 3 percent sucrose solution. However, adding dry yeast to wheat flour during the mixing phase of breadmaking maintained maximum yeast viability. Dry yeast would be especially useful in industry and research in many areas of the world, and in the military services during peacetime and war, where it is not feasible to regularly receive fresh supplies of good compressed yeast.

Effect of Type and Amount of Mixing and Quantity of Water on Inhibitors of Yeast Activity in Wheat Flour Doughs and Slurries

The effect of type and amount of mixing and quantity of water differentially influenced the effect of antimicrobial and antimycotic agents on the activity of yeast in dough and on loaf volume of bread. Sorbic acid, an antimycotic agent, greatly inhibited gas production in doughs or slurries of bread ingredients regardless of the amount or type of mixing and the amount of water. Monolaurin and monolaurin plus antimicrobial agents had small stimulating (instead of depressing) effects on yeast activities when diluted in the slurries containing the dough ingredients and 150 percent water. Even when in doughs hand mixed for 2 min, monolaurin and monolaurin plus inhibitied yeast activates only somewhat. Yeast activities were materially inhibited by those two microbicides only after the doughs received appreciable amounts of mechanical mixing (an important phase of breadmaking). When it is desirable to know whether a chemical will impair yeast activity in breadmaking, gas production tests should be made on doughs that contain the breadmaking ingredients and are mechanically mixed to optimum. Dead yeast cells increased with decreasing yeast activity of doughs that containing monolaurin and were mechanically mixed.

Pelshenke (Wheat Meal Fermentation) Test and Its Value in Estimating Functional (Breadmaking) Properties

The Pelshenke test was evaluated for precision and possible sources of variation. The Pelshenke value of dough made with dry yeast was lower and had a smaller standard deviation than that of dough made with compressed yeast. The factor responsible for the lowered values was water soluble, low in molecular weight, and tentatively identified as glutathione leached from damaged dry yeast cells. Variations in hand mixing did not appear to affect the Pelshenke value. Pelshenke values were essentially constant for variations of 12.1 to 15 percent in protein content of 'Cloud' hard winter wheat grown at one location. However, when the environment varied greatly (23 locations) throughout the Great Plains and inherent quality was still kept constant, Pelshenke value was significantly correlated ($r = 0.60$) with wheat protein content that varied from 8.8 to 16.2 percent; but 64 percent of the variability in Pelshenke value was attributed to environmental factors other than protein content.

Loaf volume (LV) (index of protein quality per unit of protein) and wheat protein content of the same 23 samples were very highly correlated (r = 0.986). Thus, nearly all of the variability in LV was attributed to protein content alone. LV of the 23 location samples was significantly correlated with Pelshenke value (r = 0.57), but only about 32 percent of the variations in LV was accounted for by variations in Pelshenke value. Variations in mixing time within an inherent quality level (23 location samples) appeared to reflect the effects of environments to about the same extent as the variations in Pelshenke value. When the environment was constant and inherent quality of wheat varied, LV of 83 variety composite flours was significantly correlated with Pelshenke value (r = 0.34), but the relationship was of no practical value for predicting LV from Pelshenke value. Dough-mixing time to the peak of the 83 flours was significantly correlated with Pelshenke value (r = 0.61), but the relationship was of little practical value for predicting mixing time. Thus, it appears that Pelshenke value is largely a function of the environment and is related to quality and quantity of bread wheat protein only to a very limited (impractical) extent.

Breadmaking Method for 10-Gram Flour

A breadmaking method for 10-g flour has been used extensively since 1964. During that period improvements in equipment and techniques have been made. Recently, additional improvements have been made in the dough molder, bread pans, and LV-measuring apparatus. LV's by the 10-g and 100-g methods were correlated after baking flours that varied in protein content from 7.4 to 17.2 percent (r = 0.985 and r = 0.991) and fractionated and reconstituted flours that varied in LV potential (r = 0.98). The 10-g method is replicable and is an invaluable tool when the amount of material is limiting. Fractionating and reconstituting studies would be impractical without it.

ECONOMIC RESEARCH SERVICE

National Economics Division

Research activity of this unit encompasses the economic evaluation of a wide range of subjects related to producing and marketing grain and grain products. General research areas include grain quality, production costs, storage, marketing margins, and transportation analysis. Special areas of research include assessing such current issues as dust emission and solar-grain drying.

Main objectives of these economic evaluations are (1) to provide economic assessments of new technologies and approaches to grain production and marketing, such as comparing costs of solar and conventional grain-drying systems and estimating costs of pelletizing grain dusts; (2) to analyze the efficiency of assembling, processing, and distributing grain and grain products; (3) to conduct supply-demand analyses; (4) to estimate costs of producing and marketing grains and grain products, including white pan bread; and (5) to provide quick analyses of current topics.

Basic to the research efforts of this group, headquartered in Washington, D.C., is the interdisciplinary approach and environment afforded by USGMRL. This unit works in close cooperation with USDA's ARS personnel, as well as with personnel at Kansas State University. Research during the past year has been in the following areas.

Economic Evaluation of Solar Collectors for Agricultural Uses

Alternative technologies and designs of multipurpose solar collector systems are evaluated in terms of payback and other economic performance measures. Technological progress is monitored and estimates of potential agricultural uses are made to predict the role of solar as an alternative energy. Special attention is given to problems associated with the introduction of homemade collectors, specifically the need for value certification for lending and tax credit purposes.

Grain Dust Problems and Utilization

Problems associated with marketing grain dust collected by dust collection systems in grain-handling operations are monitored. Alternative uses of grain dust are evaluated in terms of relative economic value of possible substitutes. Attention is called to areas of research that need emphasis.

White Pan Bread Marketing Spreads

The National Economics Division has responsibility for determining white pan bread marketing spreads. These spreads are a part of the Division's long-term effort to monitor the performance of the U.S. food marketing system. Quarterly reports are prepared at USGMRL for release in Washington, D.C.

VISITORS TO THE U.S. GRAIN MARKETING RESEARCH LABORATORY

Many hundreds of visitors to the U.S. Grain Marketing Research Laboratory came from 33 states of the United States and 52 countries throughout the world. It is impossible in the short space available to list all the distinguished visitors.

We would like, therefore, to acknowledge here the major groups that came at the invitation of several sponsoring organizations. The Kansas Wheat Commission in cooperation with U.S. Wheat Associates, Inc., and USDA's Foreign Agricultural Service sponsored wheat teams from Belize, East Germany, Guatemala, Japan, Kenya, Korea, Mexico, and the Philippines. Participants in short courses on milling, organized by Kansas State University, came from Brazil, Canada, Chile, Egypt, Japan, Jordan, Portugal, Saudi Arabia, Sudan, and Thailand. A course organized by the International Grains Program brought visitors from Bolivia, Chile, Columbia, Guatemala, Indonesia, Jamaica, Mexico, Nicaragua, Peru, Spain, and Venezuela. Our work on grain storage and marketing was described to visitors from Bangladesh, Cameroon, Costa Rica, El Salvador, Ghana, Honduras, Jordan, Mexico, Malaysia, Nigeria, Rwanda, Senegal, Sierra Leone, and Tanzania. An AID program included participants from Bangladesh, Haiti, Honduras, Kenya, Philippines, and Tanzania.

We were visited by large groups of farmers, bakers, and teachers. Several large groups of participants in short courses organized by the American Institute of Baking visited our facilities. Kansas State University sponsored tours of classes in agronomy, biology, biochemistry, crop science, and agricultural engineering.

And last, but certainly not least, we were visited by many groups representing the general public, clubs, schools, colleges, and companies. The frequent and, to the best of our knowledge, only complaint we received was in the form of a regret that not enough time was scheduled for a more thorough and detailed visit.

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_____ April 25, 1981. Factors involved in the metabolism of malathion by stored grain. Annual Meeting, Central States Entomological Society, Stillwater, Okla.

Bechtel, D. B. October 10, 1980. Membrane development during *Bacillus thuringiensis* sporulation. VIII International Spores Conference, Woodshole, Mass.

_____ October 14, 1980. Sporulation in *Bacillus thuringiensis*. Seminar at Department of Biology, State University of New York, Stoneybrook.

_____ November 20, 1980. Protein body initiation and development during cereal endosperm differentiation. Cell and Development Biology Seminar, Division of Biology, Kansas State University, Manhattan.

_____ Andrews, R. E., and Bulla, L. A., Jr. March 5, 1981. Electron microscope study of spore germination and outgrowth of *Bacillus thuringiensis*. 81st Annual Meeting, American Society for Microbiology, Dallas, Tex.

Beeman, R. W. November 30-December 4, 1980. Esterase in relation to malathion resistance in the Indian mealmoth *Plodia interpunctella*. National Meeting Entomological Society of America, Atlanta, Ga.

_____ May 1, 1981. Insecticide resistance in stored product insects. Department of Entomology, Kansas State University, Manhattan.

Boles, H. P. June 3-4, 1981. NC-151 Workshop on Breeding for Kernel Integrity and Mold and Insect Resistance in Corn. Iowa State University, Ames.

_____ August 3-8, 1981. Discussion leader on stored product insects. 52nd Rocky Mountain Conference of Entomologists, Cameron Pass, Colo.

Chang, C. S., and Martin, C. R. December 15-18, 1981. Rheological properties of grain dust. Winter Meeting, American Society of Agricultural Engineers, Chicago, Ill. ASAE Paper No. 81-3560.

Dziadik-Turner, C. A. April 9, 1981. Characterization of exochitinases and β-*N*-acetylglucosaminidases from insect hemolymph, molting fluid and cell culture media. Department of Biochemistry, Kansas State University, Manhattan.

Fan, L. T., Shieh, J. H., and Lai, F. S. August 11-14, 1981. Multiobjective optimization of a grain drying process. International Symposium on Cereals: A Renewable Resource, Copenhagen, Denmark.

Finney, K. F. March 5, 1981. Quality of Kansas wheat varieties. 9th Annual Wheat Marketing Field Day, Oberlin, Kans.

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Heid, W. G. September 11, 1980. Solar-supplemented natural air grain drying. Seminar, Agricultural Engineering Department, Kansas State University, Manhattan.

_____ December 1, 1980. Economic tools for achieving comparability in analysis of solar demonstration farm projects. ARS-ES Project Planning Committee—Livestock and Grain Drying Projects, Chicago, Ill.

_____ June 25, 1981. On-site determination of value-in-use for homemade solar collectors. Keynote paper, Small Farm Energy Project's Workshop on System-Dependent Evaluation of Farm Energy Innovations, Doane College, Crete, Nebr.

Hoveland, D. A., Walawender, W. P., Fan, L. T., and Lai, F. S. December 15-18, 1981. An experimental study of stream gasification of grain dust in fluidized-bed reactor. Winter Meeting, American Society of Agricultural Engineers, Chicago, Ill.

Jones, B. L. February 17, 1981. The inheritance of purothionins in wheats and wheat relatives. Seminar—Kansas State University Plant Genetics Discussion Group, Manhattan.

Koga, D., Turner, C. D., Mai, M. S., and Kramer, K. J. June 2, 1981. Purification and characterization of exochitinases from insect molting fluid and hemolymph. Annual Meeting, American Society of Biological Chemists, St. Louis, Mo.

Kramer, K. J. June 16, 1981. Biochemistry of growth and development. Departments of Chemistry and Biology, University of Indiana, Evansville.

Lai, F. S. May 25-26, 1981. Construction, dust control and explosion prevention equipment.
(1) Unloading to silos
(2) Silos to processing (flour mill, feed mill, soybean crushing, and extraction)
(3) Processing to storage
Seminar on Grain and Flour/Meal Handling and Storage, sponsored by American Soybean Association, U.S. Feed Grain Council, and U.S. Wheat Associates in cooperation with the National Logistics Agency, Republic of Indonesia, Jakarta.

_____ September 16, 1981. Oil treatment makes grain dust easier to handle. Governor's Task Force on Grain Dust Explosions, Nebraska Grain and Feed Dealers Association, Lincoln.

Martin, C. R., Aldis, D. F., and Lee, R. S. December 4, 1980. *In situ* measurement of grain dust particle size distribution and concentration. Winter Meeting, American Society of Agricultural Engineers, Chicago, Ill.

McGaughey, W. H. November 30-December 4, 1980. Moderator, informal conference on Control of Stored Product Insects. Annual meeting, Entomological Society of America, Atlanta, Ga.

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_____ January 16, 1981. *Bacillus thuringiensis* for stored product insect control. Department of Entomology, Kansas State University, Manhattan.

_____ August 2-4, 1981. Progress on pilot testing methods of applying *Bacillus thuringiensis* to stored grain. 52nd Rocky Mountain Conference of Entomologists, Gould, Colo.

Pomeranz, Y. October 6-11, 1980. South American Short Course on Wheat Science and Technology, Buenos Aires, Argentina.
(1) Wheat history, production, statistics
(2) Grain hardness
(3) Wheat structure and composition
(4) High protein foods from cereals
(5) Biochemistry of breadmaking
(6) Flour supplementation
(7) Storage of wheat and milled wheat products
(8) Quality control

_____ October 6, 1980. Research activities of the USGMRL. Foundation Ciepe, San Felipe, Venezuela.

_____ October 20, 1980. Bringing the laboratory into the field and the field into the laboratory. Wiley Award Address, 94th Annual meeting, Association of Official Analytical Chemists, Washington, D.C.

_____ November 19, 1980. Research activities of the USGMRL. Research Committee, Annual Meeting, National Association of Wheat Growers, Minneapolis, Minn.

_____ February 13, 1981. Flour Supplementation Short Course, Near East (Egypt, Jordan, Sudan) Milling Team, Kansas State University, Manhattan.

_____ March 31, 1981. Flour Supplementation Short Course, Yugoslavian Milling Team, Kansas State University, Manhattan.

_____ April 13, 1981. Research activities of the USGMRL. Nabisco Inc., East Hanover, N.J.

_____ May 5-8, 1981. Short Course in Cereal Science and Technology, Foundation Ciepe, San Felipe, Venezuela.
(1) Structure and composition of cereal grains
(2) High protein foods from cereals
(3) Biochemistry of breadmaking
(4) Flour supplementation
(5) Grain storage
(6) Quality control
(7) Cereal grains: history, production, statistics
(8) Grain standards
(9) Starches
(10) Products of starch processing

_____ May 26, 1981. The science of breadmaking. Braverman Memorial Lecture, Technion-Israel Institute of Technology, Haifa, Israel.

_____ May 27, 1981. Nutritional improvement of cereals. Department of Agricultural Biochemistry, Hebrew University, Jerusalem, Rehovoth, Israel.

_____ May 28, 1981. The biochemistry of breadmaking. Institute for Desert Research, Sde Boker, Israel.

_____ May 28, 1981. Molecular approach to breadmaking. Faculty of Health Sciences, Biochemistry, School of Medicine, University of Negev, Beer Sheva, Israel.

_____ June 1, 1981. Flour improvers. Joint Seminar, Israeli Flour Millers and Bakers Association, Jerusalem, Israel.

_____ June 8, 1981. Flour supplementation. Association of Operative Millers, Kansas State University, Manhattan.

_____ June 30, 1981. Flour treatment. Portuguese Speaking Milling Short Course, Kansas State University, Manhattan.

_____ August 11, 1981. Introduction, Cereals: A Renewable Resource. International Symposium, Cochairman, Copenhagen, Denmark.

_____ August 13, 1981. Wheat and triticale—A multiple approach for use as a renewable resource. International Symposium, Copenhagen, Denmark.

_____ August 14, 1981. Wrap up and round table discussion, Cereals: A Renewable Resource, International Symposium, Copenhagen, Denmark.

_____ August 17, 1981. Biochemical basis of breadmaking. Norwegian Cereal Association, Oslo, Norway.

_____ September 10, 1981. Cereal science and technology at the turn of the decade. Warsaw Agricultural University, Poland.

_____ September 11, 1981. Structure, composition, and end use properties of cereal grains. Institute of Human Nutrition, Academy of Agriculture, Poznan, Poland.

_____ September 14, 1981. Research activities of the USGMRL as related to variety testing. Research Center for Testing Varieties, Slupia Wielka, Poland.

Quinlan, J. K. March 27, 1981. Method and equipment for bulk treatment of grain with protectants for insect control. Central States (Kansas) Entomological Society, Stillwater, Okla.

_____ August 6, 1981. Chlorpyrifos-methyl applied as a protectant for stored wheat. 52nd Rocky Mountain Conference of Entomology, Gould, Colo.

Sauer, D. B. October 20-25, 1980. Fungi in grain: Their significance and control. Coloquio Internacional Sobre Conservacion de Semillas y Granos Almacenados, Oaxtepec, Morelos, Mexico.

_____ March 23-24, 1981. Sources of inoculum of *Aspergillus flavus* and risk of aflatoxin development during drying and storage of corn. Aflatoxin Workshop, Columbia, Mo.

_____ June 3-4, 1981. Resistance of corn to infection by storage fungi. NC-151 Workshop on breeding for Kernel Integrity and Mold and Insect Resistance in Corn, Ames, Iowa.

Schnake, L. D. September 25, 1980. White pan bread marketing spreads; revisions. Technical Committee, Association of Operative Millers, Manhattan, Kans.

_____ November 6, 1980. Needs for research on U.S. grain quality. Remarks at the ARS NPS Review of the USGMRL Biological Unit, Manhattan, Kans.

_____ November 7, 1980. Grain dust research needs. Remarks at the ARS NPS Review of the USGMRL Engineering Unit, Manhattan, Kans.

_____ March 18, 1981. Grain dust: Problems and utilization. International Meeting, Grain Elevator and Processing Society, New Orleans, La.

_____ May 15, 1981. What is being done to deliver the quality of grain that the importer contracts. International Grains Program, Mini-Short Course, Manhattan, Kans.

_____ September 1, 1981. U.S. white pan bread marketing spreads. Seminar, U.S. Department of Agriculture, Economic Research Service, Washington, D.C.

_____ September 16, 1981. USDA white pan bread marketing spreads, an update. Technical Committee, Association of Operative Millers, Manhattan, Kans.

Storey, C. L. October 22, 1980. Chemical and nonchemical control of stored product insects. Coloquio Internacional Sobre Conservacion de Semillas y Granos Almacenados, Oaxtepec, Morelos, Mexico.

_____ March 24, 1981. Chemical pesticides: Review of current research and suitable alternatives. Allied Industrial Workers National Conference on Health and Safety Hazards in the Grain Industry and Allied Traders, St. Louis, Mo.

_____ Sauer, D. B., and Ecker, O. April 21, 1981. Insects and fungi in U.S. wheat and corn exports. Report to the Federal Grain Inspection Service, Washington, D.C.

SEMINARS PRESENTED AT THE U.S. GRAIN MARKETING RESEARCH LABORATORY

Bulla, L. A., Jr. January 21, 1981. Molecular biology of *Plodia interpunctella* virus. U.S. Grain Marketing Research Laboratory, Manhattan, Kans.

Chatterjee, A. January 28, 1981. Genetics of *Erwinia Species*. Department of Plant Pathology, Kansas State University, Manhattan.

Clark, S. March 11, 1981. Gasification of crop residues for engine fueling and crop drying. Department of Agricultural Engineering, Kansas State University, Manhattan.

Eriksson, C. November 13, 1980. Anti-oxidative and antimicrobial Maillard reaction products, model and application studies. SIK-The Swedish Food Institute, S-400 23 Goteborg, Sweden.

Fately, W. April 1, 1981. April food. Department of Chemistry, Kansas State University, Manhattan.

Fretzdorff, B. April 29, 1981. Determination of peroxidase and β-xylosidase activity in cereals. Federal Research Centre of Grain & Potato Processing, D-4930 Detmold, West Germany.

Fry, R. February 4, 1981. New directions in plasma atomic emission spectroscopy. Department of Chemistry, Kansas State University, Manhattan.

Helgesen, R. February 11, 1981. The development of an alfalfa pest management program. Department of Entomology, Kansas State University, Manhattan.

Hopkins, T. February 25, 1981. Biochemistry of insect cuticle. Department of Entomology, Kansas State University, Manhattan.

Iandolo, J. March 25, 1981. Genetic regulation of staphylococcal enterotoxin. Department of Biology, Kansas State University, Manhattan.

Kameyama, Y. April 15, 1981. Risk analysis of grain processing and handling operations for prevention of dust explosions and fires. Yokama University, Hiroshima, Japan.

Lee, R. February 18, 1981. Dust explosion in a 20-liter spherical bomb. Department of Physics, Kansas State University, Manhattan.

Meredith, P. July 15, 1981. Mainly about New Zealand with a little science too. Wheat Research Institute, Christchurch, New Zealand.

_____ July 22, 1981. Starch. Wheat Research Institute, Christchurch, New Zealand.

Muthukrishnan, S. March 4, 1981. Hormonal control of α-amylase synthesis in barley. Department of Biochemistry, Kansas State University, Manhattan.

Seib, P. April 22, 1981. Oriental noodles—types and production. Department of Grain Science and Industry, Kansas State University, Manhattan.

Shellenberger, J. January 14, 1981. How we arrived at where we are today. Department of Grain Science and Industry, Kansas State University, Manhattan.

Uyemoto, J. April 8, 1981. Plant virus research with emphasis on maize chlorotic mottle virus. Department of Plant Pathology, Kansas State University, Manhattan.

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